National Aeronautics and
Space Administration

ESMD-RQ-0027
Preliminary (Rev. A)
Effective Date: 2 June 2005

Exploration Systems Mission Directorate

National Aeronautics and Space Administration, Headquarters
Washington DC 20546-0001

Exploration In-Space Support System Requirements Document

Version Preliminary – Revision A
2 June 2005

Document History Log

Status (Baseline/Revision/ Cancelled)	Document Revision	Effective Date	Description
Preliminary	-	Feb 2005	
Preliminary (Rev. A)	Completion of ESMD, NASA HQS, and NASA Field Center Reviews	June 2, 2005	

In-Space Support System Requirements Document

Submitted By:

Michael F. Lembeck, PhD Director, Requirements Formulation Division Exploration Systems Mission Directorate	Date

Concurred by:

Jim Nehman Director, Development Programs Division Exploration Systems Mission Directorate	Date

Approved by:

Craig E. Steidle Associate Administrator for Exploration Systems	Date

This page intentionally left blank

Table of Contents

This page intentionally left blank

1 Scope

1.1 Identification

This document is a summary of the NASA In Space Support System (IS^3) Requirements. When combined with the Exploration System of Systems (ESS)Technical Requirements Document (ESMD-RQ-0010), they represent a first-level functional decomposition of requirements expressed in The Vision for Space Exploration (The Vision), NP-2004-01-334-HQ, February 2004. The Vision is expressed in requirements form in the Level 0 Exploration Requirements for the National Aeronautics and Space Administration, SA-0001, May 4, 2004.

The capabilities expressed in this document will evolve and expand over time, employing the Spiral Development Process to provide the communication, navigation, and other infrastructural support required to enable human-crewed, cargo, and robotic flight and ground systems to accomplish The Vision. Currently, the emphasis has been on Exploration Spirals 1 through 3, which culminate with long-duration human exploration of the Moon. Requirements development for Spiral 4 and beyond (human-Mars exploration) will be undertaken in the future, and this document will be updated. The controlling authority for this document is the Exploration Systems Mission Directorate (ESMD), Requirements Formulation Division, NASA Headquarters.

1.2 Document Overview

This document provides the requirements for IS^3 that will enable successful Exploration missions. Since the IS^3 is a supporting set of capabilities, its scope is dependent upon the ESS architecture chosen to execute mission(s). IS^3 provides capabilities for space-based infrastructure elements (e.g., communications, navigation, surveillance), that are placed in orbital or in some cases lunar/planetary locations, and their corresponding ground-based operation (e.g., a ground station or antenna). The Exploration Systems Document Tree shown in Figure 1 explains the hierarchy of requirements documents that flow down from The Vision. The relationship of this document to other Exploration Systems requirements documents is shown in Figure 2.
Note: Where a requirement is expressed with "threshold and objective" values, it has been determined that performance above the threshold (minimum performance level) is of value to NASA as a desired "objective". Where no objective value is expressed, the value shown is the threshold requirement.
Section 1 of this document contains background information with no direct requirements. Section 2 contains the applicable documents that the In Space Support System (IS3) must comply with, as specified; Section 2 also includes reference documents that are for information only, and do not contain compliance requirements. Section 3 contains requirements that begin in Section 3.1. Section 4 is reserved for verification. Actual verification requirements do not appear in this document, and will be treated in lower level requirements documents. Section 5 provides a glossary of Exploration terms, an acronym list, a requirements taxonomy table, and requirements traceability tables that express requirements flow-down.

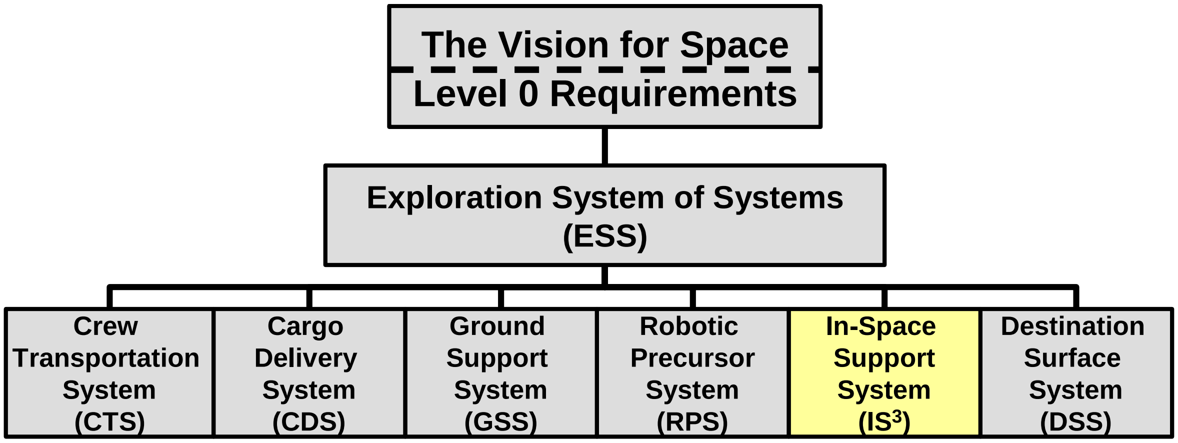

Figure 1: System Hierarchy

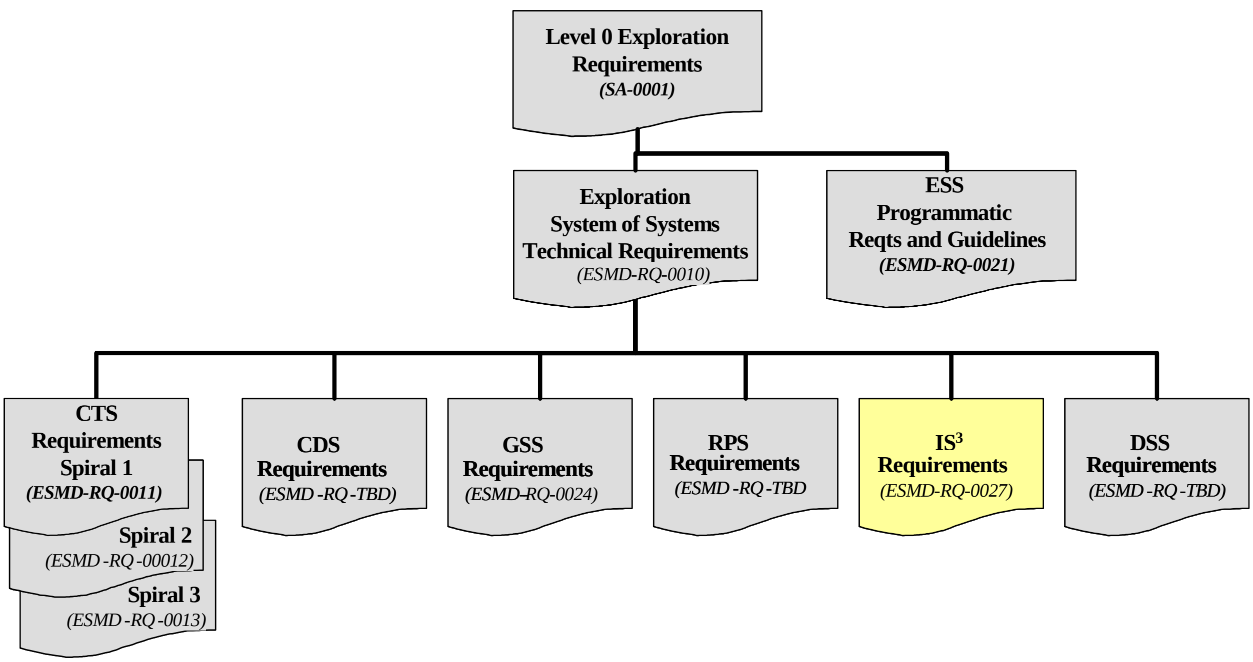

Figure 2: Exploration System Requirements Tree

2 Documents

2.1 Applicable Documents

The following documents form a part of this requirements document to the extent specified herein or in total if not specified. The version of the document applicable will be the latest revision at the time of contract award unless otherwise specified.

2.1.1 Government Documents

The Vision for Space Exploration (NP-2004-01-334-HQ)

Level 0 Exploration Requirements for the National Aeronautics and Space Administration (SA-0001)

NPR 7150.2, NASA Software Engineering Requirements

NPD 8710.3, NASA Policy for Limiting Orbital Debris Generation

NPR 8705.2 Human Rating Requirements and Guidelines for Space Flight Systems

NPR 8715.3, NASA Safety Manual

NASA STD 8719.13, Software Safety NASA Technical Standard

NPR 2810.1, Security of Information Technology Security

Crew Transportation System (CTS) / In-Space Support System IRD **(TBD-68)**

Ground Support System (GSS) / In-Space Support System IRD **(TBD-12)**

Robotic Precursor System (RPS) / In-Space Support System IRD **(TBD-89)**

Cargo Delivery System (CDS) / In-Space Support System IRD **(TBD-90)**

Destination Surface System (DSS) / In-Space Support System IRD **(TBD-91)**

Exploration System of Systems (ESS) Interface Standards Document **(TBD-66)**

ESMD-RQ-0010 Exploration System of Systems (ESS) Technical Requirements Document

2.1.2 Non-Government Documents

Reserved.

2.2 Reference Documents

The following documents specified herein are for reference only. Current document versions are referenced.

2.2.1 Government Documents

ESMD-RQ-0005, Lunar Architecture Focused Trade Study Final Report
ESMD-RQ-0006, Lunar Architecture Broad Trade Study Final Report
ESMD-RQ-0016, STTP-2 Meeting Minutes

ESMD-RQ-0018, Draft Polar Lunar Landing Site Rationale
ISBN 0-309-07031, Astronomy and Astrophysics in the New Millennium, National Academies of Science
NASA-STD-3000, Vol. I-IV, Man-Systems Integration Standards
NPR 1000.2, NASA Strategic Management Handbook
NPD 1050.1G, Authority to Enter into Space Act Agreements
NPD 1080.1A, NASA Science Policy
NPD 1200.1B, Internal Management Controls and Audit Liaison
NPD 1280.1, NASA Management System Policy
NPD 1360.2A, Initiation and Development of International Cooperation in Space and Aeronautics Programs, NPD 1360.2A
NPR 1385.1, Public Appearances of NASA Astronauts and Other Personnel
NPD 1387.1E, NASA Exhibits Program
NPR 1387.1, NASA Exhibits Program
NPD 1387.2F, Use, Control, and Loan of Lunar Samples for Public and Educational Purposes
NPD 1600.2C, NASA Security Policy
NPR 1620.1A, Security Procedural Requirements
NPR 1800.1, NASA Occupational Health Program Procedures
NPR 1800.2B, NASA Occupational Health Program
NPD 1810.2, NASA Occupational Medicine Program
NPD 1820.1B, NASA Environmental Health Program
NPD 2200.1, Management of NASA Scientific and Technical Information (STI)
NPR 2200.2A, Requirements for Documentation, Approval, and Distribution of NASA Scientific and Technical Information (STI)
NPD 2800.1, Managing Information Technology
NPR 2800.1, Managing Information Technology
NPD 2810.1C, NASA Information Security Policy
NPD 2820.1A, NASA Software Policies
NPD 3310.1A, Distinguishing between Contractor and Civil Service Functions
NPD 5101.32B, Procurement
NPR 5600.2B, Statement of Work (SOW); Guidance for Writing Work Statements
NPR 6000.1F, Requirements for Packaging, Handling, and Transportation for Aeronautical and Space Systems, Equipment, and Associated Components
NPD 7100.10D, Curation of Extraterrestrial Materials
NPD 7120.4B, Program/Project Management
NPR 7120.5C, NASA Program and Project Management Processes and Requirements Approval Authorities for Facility Projects.
NPD 7330.1F, Approval Authority for Facility Projects
NPD 7500.1A, Program and Project Logistics Policy
NPR 7500.1, NASA Technology Commercialization Process
NPR 8000.4, Risk Management Procedural Requirements
NPD 8020.7F Biological Contamination Control for Outbound and Inbound Planetary Spacecraft
NPR 3020.12B, Planetary Protection Provisions for Robotic Extraterrestrial Missions
NPD 8610.7A, Launch Services Risk Mitigation Policy for NASA -Owned Or NASA -Sponsored Payloads
NPD 8610.23A, Technical Oversight of Expendable Launch Vehicle (ELV) Launch Services
NPD 8610.24A, Expendable Launch Vehicle (ELV) Launch Services Pre-launch Readiness Reviews
NPD 8700.1B, NASA Policy for Safety and Mission Success

NPD 8700.2A, NASA Policy for Safety and Mission Assurance (SMA) for Experimental Aerospace Vehicles (EAV)
NPD 8700.3A, Safety and Mission Assurance (SMA) Policy for NASA Spacecraft, Instruments, and Launch Services
NPR 8705.3, Safety and Mission Assurance (SMA) Requirements for Experimental Aerospace Vehicles (EAV)
NPR 8705.4, Risk Classification for NASA Payloads
NPR 8705.5, Probabilistic Risk Assessment (PRA) Procedures for NASA Programs and Projects
NPR 8715.1, NASA Safety and Health Handbook Occupational Safety and Health Programs
NPD 8720.1B, NASA Reliability and Maintainability (R&M) Program Policy
NPD 8730.2B, NASA Parts Policy
NPD 8730.4A, Software Independent Verification and Validation (IV&V) Policy
NPR 8735.2, Management of Government Safety and Mission Assurance Surveillance Functions for NASA Contracts
NPD 8820.2A, Design and Construction of Facilities
NPR 8820.2E, Facility Project Implementation Guide
NPD 8820.3, Facility Sustainable Design
NPD 8900.1F, Medical Operations Responsibilities in Support of Human Space Flight Programs
NPD 9501.1G, NASA Contractor Financial Management Reporting System
NPR 9501.2D, NASA Contractor Financial Management Reporting
NPD 9501.3A, Earned Value Management
NPR 9501.3, Earned Value Management Implementation on NASA Contracts

2.2.2 Non-Government Documents

Reserved.

3 In-Space Support System (IS^3) Requirements

The following text does not provide, nor represent specific requirements, but is provided as context for the requirements that follow, beginning in section 3.1.

System Description
The Vision for Space Exploration requires NASA to implement an effective and exciting program of exploration and discovery. Sustained and affordable human and robotic missions will extend the human presence across the solar system. Innovative technologies, knowledge, and infrastructures will need to be developed. Over the next two decades, NASA plans to develop a number of new capabilities and systems that are critical to enabling safe and successful human and robotic missions. Vehicle elements to be fielded within this System of Systems will use a “spiral development” approach. In spiral development, the detailed end-state requirements are not known at program initiation. Requirements are refined through system development and demonstration, risk management and continuous user feedback. This approach will build on the experience gained in early Exploration Spirals, to provide flexibility in responding to scientific discoveries and to incorporate new technologies. Robotic Precursor Missions to the Moon and Mars will provide information necessary to conduct future human exploration (i.e., topography mapping, gravity maps, resource identification). In addition, Robotic Precursor Missions will serve as opportunities for advanced technology demonstrations.

Exploration Spiral 1/Crew Exploration Development and Test

Exploration Spiral 1 will establish the capability to test and checkout Crew Transportation System (CTS) elements in Low Earth Orbit (LEO) in preparation for future human exploration missions to the Moon. The capabilities necessary to satisfy the Spiral 1 objectives consist of a Crew Exploration Vehicle (CEV), a Crew Launch Vehicle (CLV), and ground support infrastructure. The CEV and CLV will safely transport the crew from the surface of the Earth to LEO, and return them to the Earth's surface at the completion of the mission. Demonstration of CEV and launch system performance are critical to enabling Spiral 1 objectives of safe transportation of the crew. Successive demonstrations of the CEV and launch system (including the ability to perform ascent and entry aborts) will begin with a series of risk reduction flight tests, and lead up to crewed CEV operational capability to support human exploration missions beyond LEO. The CEV must have a high degree of automated control to accomplish the early un-crewed test flights. As exploration capabilities necessary for future spirals are developed, they will be tested with the CEV in the space environment to prepare for future exploration missions. Robotic exploration missions during Spiral 1 will investigate the lunar environment and provide the needed information to prepare for safe landings and human exploration of the lunar surface. Robotic missions will also develop and mature autonomous technologies for use in the CEV.

<u>Spiral 1 Flight Hardware Functional Descriptions:</u>

Crew Launch Vehicle:

> Will provide the propulsive force necessary to launch the CEV into LEO.

Crew Exploration Vehicle:

> Will provide the necessary crew habitation and crew health maintenance functions during the ascent, on-orbit, and entry phases of the mission, including aborts. Will also provide all maneuvering capability during orbit operations and entry (including entry phase of an abort). Will provide for contingency EVA capability.

In Space Support System:

> Will provide the communications and navigation infrastructure for communication between ESS elements and radiometric navigation of ESS elements. This infrastructure will include communication satellites, ground stations and beacons on or near Moon and Earth. Will provide interoperable command, control and communication standards for all ESS elements.

Robotic Precursor System:

> Will provide measurements, technology demonstrations, and may provide infrastructure in advance of human missions.

Ground Support System:

> Ground based facilities and capabilities will provide the ability to plan, train, process, launch, operate flight systems, as well as land, recover, refurbish or dispose of those systems.

Exploration Spiral 2/Global Lunar Access for Human Exploration

Exploration Spiral 2 will establish the capability to conduct human exploration missions to any location on the surface of the Moon without pre-positioned surface infrastructure. This Spiral 2 capability will likely be utilized to conduct human exploration of potential lunar base sites prior to the delivery of habitats and surface power systems (Destination Surface Systems). This capability could also be utilized to place humans at the lunar base camp location for habitat and surface power systems final assembly tasks. Once the lunar base is established, this Spiral 2 capability could be utilized to explore locations which are not accessible via surface mobility assets. The systems necessary to satisfy Spiral 2 objectives consist of those developed in Exploration Spiral 1, or derivatives of those systems, plus Earth Departure Stage(s) (EDS) necessary to transport elements to the lunar vicinity as well as the Lunar Surface Access Module (LSAM) that will provide the capability for the crew to access the lunar surface. The Cargo Delivery System will deliver un-crewed elements of the Crew Transportation System into LEO and/or lunar orbit (e.g., EDS). Spiral 2 will include successive flight tests to demonstrate the flight characteristics of the CEV, EDS, and LSAM to gain knowledge of how the systems perform at greater distances from Earth and increasing levels of autonomy. Focused robotic precursor technology demonstration missions to Mars are also anticipated within this Spiral.

<u>Spiral 2 Flight Hardware Functional Descriptions:</u>

Crew Launch Vehicle:

> Will provide the necessary propulsive force to launch the CEV and other mission elements into LEO.

Crew Exploration Vehicle:

> Will provide the necessary crew habitation and crew health maintenance functions from launch to lunar orbit and return to the Earth surface, including aborts during Earth ascent. The CEV will also provide the necessary propulsive accelerations to return the mission crew from lunar orbit, independent of orbital alignment, for direct entry at Earth. The CEV will rendezvous and dock with other mission elements, such as the EDS and LSAM, in both LEO and lunar orbit. In addition, the CEV will operate un-crewed in lunar orbit while the crew is on the surface of the Moon. Will provide for contingency EVA capability.

Earth Departure Stage(s):

> Will provide the necessary propulsive accelerations needed to transfer the various flight elements (CEV and LSAM) from LEO to lunar orbit, and provide the deceleration for lunar orbit insertion.

In Space Support System:

> Will provide the communications and navigation infrastructure for communication between ESS elements and radiometric navigation of ESS elements. This infrastructure will include communication satellites, ground stations and beacons on or near Moon and Earth. Will provide interoperable command, control and communication standards for all ESS elements.

Lunar Surface Access Module:

> Will provide the necessary crew habitation, crew health maintenance, and transportation functions from lunar orbit to the lunar surface and during return to lunar orbit; will provide crew habitation during lunar surface operations. In addition, the LSAM will provide the capability for the crew to conduct science and perform routine Extra-Vehicular Activity (EVA) on the surface of the Moon.

Cargo Delivery System:

Will deliver un-crewed elements of the CTS into LEO and/or lunar orbit. CDS elements include the Cargo Launch Vehicle and the EDS.

Robotic Precursor System:

Will provide measurements, technology demonstrations, and may provide infrastructure in advance of human missions.

Ground Support System:

Ground based facilities and capabilities will provide the ability to plan, test, train, process, launch, operate flight systems, as well as land,recover, refurbish or dispose of those systems.

Exploration Spiral 3/Lunar Base and Mars Testbed

Exploration Spiral 3 will establish the capability to conduct routine human long-duration missions at a lunar base to test out technologies and operational techniques for expanding the human presence to Mars and beyond. Missions in Spiral 3 will extend up to several months in duration at the lunar poles or equatorial region in order to serve as an operational analog of future Mars missions. Spiral 3 will require the development and deployment of habitats and surface power systems. These Destination Surface Systems (DSS) will be delivered to a selected location in the polar or equatorial region by the Cargo Delivery System (CDS). The number, type, and sequencing of these CDS missions have not yet been specifically defined. Once the surface systems are in place, successively longer missions will be conducted to increase the understanding of system technical performance (including health and human systems), and to provide increasing levels of operational autonomy capabilities that will be necessary for future human Mars exploration missions. The Spiral 2 capability for global access is retained in Spiral 3, and will allow exploration missions to locations not accessible from the base camp via surface mobility assets.

<u>Spiral 3 Flight Hardware Functional Descriptions:</u>

Crew Launch Vehicle:

Will provide the necessary propulsive force to launch the CEV and other mission elements into LEO.

Crew Exploration Vehicle:

Will provide the necessary crew habitation and crew health maintenance functions from launch to lunar orbit and return to the Earth surface, including aborts during Earth ascent. The CEV also will provide the necessary propulsive accelerations to return the mission crew from lunar orbit, independent of orbital alignment, for direct entry at Earth. The CEV will rendezvous and dock with other mission elements, such as the EDS and LSAM, in both LEO and lunar orbit. In addition, the CEV will operate un-crewed in lunar orbit while the crew is on the surface of the Moon. Will provide for contingency EVA capability.

Earth Departure Stage(s):

Will provide the necessary propulsive accelerations needed to transfer the various flight elements (CEV, LSAM, and cargo vehicles) from LEO to lunar orbit and provide the deceleration for lunar orbit insertion.

In Space Support System:

Will provide the communications and navigation infrastructure for communication between ESS elements and radiometric navigation of ESS elements. This infrastructure will include communication satellites, ground stations and beacons on or near Moon and Earth. Will provide interoperable command, control and communication standards for all ESS elements.

Lunar Surface Access Module:

Will provide the necessary crew habitation, crew health maintenance, and transportation functions from lunar orbit to the lunar surface, and return to lunar orbit. In addition, the LSAM will provide the capability for the crew to perform EVA on the surface of the Moon in order to transition to the surface elements for the long duration missions. The LSAM will remain on the surface of the Moon during the long-duration surface missions.

Cargo Delivery System:

Will deliver un-crewed elements of the Crew Transportation System into Low Earth Orbit and/or lunar orbit. CDS elements include the Cargo Launch Vehicle and the EDS. The CDS will also deliver elements of the DSS from a low lunar orbit to the desired location on the surface of the Moon. The CDS elements have not been completely identified at this time, but should include a Cargo Launch Vehicle, Cargo Destination Landing System, and the EDS.

Destination Surface System:

Will provide crew support capabilities to enable long-duration surface missions. The elements that comprise this system have not been completely defined at this point, but will provide functionality including habitation, communication, power, extended range mobility, enhanced science capabilities, etc. DSS will provide the capability for the crew to conduct long-duration surface science, and perform EVA on the surface of the Moon.

Robotic Precursor System:

Will provide measurements, technology demonstrations, and may provide infrastructure in advance of human missions.

Ground Support System:

Ground based facilities and capabilities will provide the ability to plan, test, train, process, launch, operate flight systems, as well as land, recover, refurbish or dispose of those systems.

3.1 Mission Definition

NSS0180H The IS^3 shall distribute data between elements of the ESS.

Rationale : Distribution of data between elements of the ESS (e.g., ground control to flight vehicle) is an IS^3 responsibility. Data includes operational command & telemetry, voice, video, science data, space weather, position, velocity, system health, software uploads, file transfers, surveillance (e.g., destination surface reconnaissance), time and time synchronization, situational awareness, Space Based Range Safety, etc. Depending on the concept of operations, IS^3 may be called upon to capture, archive, make retrievable, relay, store and forward, or route data between ESS systems.

This requirement is intended as a broad parent for lower level specifications. Trade studies will be needed assess scope of IS^3 capabilities vs. capabilities elsewhere in the ESS architecture by Spiral. This also becomes a parent for lower-level requirements for IS^3 system to be available for communications coverage at a specified duration.

IS^3 relay satellites should be able to accept data from ground for maintenance, operation and control of satellite.

NSS0200H The IS^3 shall generate its system availability status data to other elements of ESS.

Rationale : This IS^3 will be required to provide system availability data to other elements of ESS. Available bandwidth, next communication opportunity, and amount of on-line storage available are examples of data that should be provided.

NSS0190H IS^3 shall generate planetary and space weather data to support ESS element mission operations.

Rationale : Where there is a gap between ESS needs and available planetary and space weather capabilities, IS^3 shall generate the necessary data. The term “generate” includes acquisition (via IS3 in-space assets) of weather data, the acquisition of weather data from non-IS3 external sources, and the necessary processing of that data for use by the ESS. Transmission of space weather data from non-IS^3 sources is covered by NSS0180H.

NSS0120H IS^3 shall provide navigation support for ESS flight elements.

Rationale : Navigation in LEO, Lunar orbit (TBD), and Earth-Lunar transfer orbits with inertial positioning and inertial velocity accuracy is required to support communications pointing, ascent, departure maneuver execution, mid-course trajectory analysis and corrections, rendezvous maneuver planning, descent, Earth entry interface maneuver execution, and landing. There is a trade between the accuracy burden placed on each spacecraft element's onboard navigation resources and the accuracy gap to be filled by IS^3. There is also a trade between the partitioning of navigation functions between the ESS flight element and the IS3 element.

3.2 Mission Success

NSS0280H The IS^3 shall provide for data and service security in compliance with NPR 2810.1, Information Technology Security.

Rationale : IS^3 must protect against accidental or intentional disruption / corruption of critical data and services. As defined in NPR 2810.1, IS^3 will produce an IS^3 Security Plan based on an assessment of the risks and vulnerabilities anticipated for each Spiral, and within each mission. The IS^3 Security Plan will define risks which must be mitigated and acceptable mitigation approaches.

3.3 Performance Characteristics

3.3.1 Operations

NSS0250H IS^3 shall provide for end-of-mission-life disposal of IS^3 elements that operate beyond Earth orbit.

Rationale : Communication and navigation satellites must eventually be decommissioned, and disposed of at end-of-life. Requirement NSS0410H covers end-of-life disposal planning for flight hardware that is in Earth orbit, or will become Earth orbital. This requirement pertains to end-of-mission life planning for IS^3 assets that are beyond Earth orbit.

3.3.2 Flight Control (Reserved)

3.3.3 Communications

NSS0220H The IS^3 shall provide for communications between ESS Systems during Mission Critical Events **(TBR-77)**.

Rationale : IS^3 has the responsibility of ensuring sufficiently available communications between elements of the ESS, where those elements are not able to provide the needed communications themselves. IS^3 has responsibility to provide capability to support Mission Critical Events. The responsible program will determine MCE's, and what IS^3 capability is required to support them (e.g., operations on the back side of the Moon). This is a parent for lower-level IS^3 communications requirements.

TBR-77 Closure Plan: Definition of Mission Critical Events is Architecture and Mission dependent. As a Spiral Mission Campaign is determined for a given ESS architecture, this item will be determined.

3.3.4 Crew Environment

3.3.5 Software

NSS0370H The IS^3 shall comply with NPR 7150, NASA Software Engineering Requirements.

Rationale : NPRs are agency level requirements and not at the discretion of the Directorate. Specific version and dates shall be identified in the spiral requirements.

3.4 Safety

3.4.1 General

NSS0320H The IS^3 shall comply with NASA STD 8719.13, Software Safety Standard, for all Safety-Critical Software.

Rationale : Software is a critical component of all complex space systems. Safety Critical Software (as defined in NASA-STD-8719.13) must be developed and tested to ensure the safety of the crew. Although 8719.13 is a standards document, it contains specific software requirements.

NSS0410H The IS^3 shall dispose of IS^3 expendable flight elements at end of life in accordance with NPD 8710.3, NASA Policy for Limiting Orbital Debris Generation.

Rationale : Disposal of any flight hardware that may generate orbital debris in Earth orbit, or may reenter the Earth's atmosphere are governed by this NPD. Abort towers, ascent stages, and earth departure stages are examples of potential flight hardware covered by this NPD.

NSS0340H The IS^3 shall comply with NPR 8715.3 NASA Safety Manual.

Rationale : NPRs are agency level requirements and not at the discretion of the Directorate. This document contains the requirements and procedures for NASA Safety Programs to minimize risk to equipment and personnel.

3.4.2 Crew Survival

NSS0330H The IS^3 components affecting crew health and safety shall comply with NPR 8705.2, Human-Rating Requirements and Guidelines for Space Flight Systems

Rationale : NPRs are agency level requirements and not at the discretion of the Directorate. In order to fly humans in space, each element of the System of Systems that interfaces with the crew must be certified as human rated. NPR 8705.2 delineates the requirements and process for obtaining that certification and is applicable to those elements that interact with the crew.

3.4.3 Vehicle Health

NSS0350H The IS^3 shall generate its system health status and provide it to other ESS elements.

Rationale : All elements must monitor internal health.

3.5 Interfaces

NSS0400H The IS^3 shall provide communication in accordance with the ESS Interface Standards Document (ISD) **(TBD-66).**

Rationale : The complexity of possible architectures and the serial acquisition of Exploration elements dictates a standard communications interface between all elements of the Exploration System of Systems. Communications includes command, telemetry, mission data, voice and video. ESS Systems must define the standard communications system in an IRD to include bandwidth, rates, security, etc.

TBD-66 Closure: Interface standards must be developed by Constellation Systems, in coordination with the ESMD Requirements Division. Closure of this item will be achieved no later than 90 days prior to the CEV SRR.

NSS0420H The IS^3 interface with the CTS shall comply with the requirements of the Crew Transportation System (CTS) / In-Space Support System IRD **(TBD-68)**.

Rationale : The CTS will interface with multiple IS^3 elements such as communications satellite systems and navigation satellite systems. A common IRD will be developed to support this interface.

TBD-68 Closure: This IRD must be developed by Constellation Systems, in coordination with the ESMD Requirements Division. Closure of this item will be achieved no later than 90 days prior to the CEV SRR.

NSS0430H The IS^3 interface with the GSS shall comply with the requirements of the Ground Support System (GSS) / In-Space Support System IRD **(TBD-12)**.

Rationale : The IS^3 will interface with the GSS to perform communication and navigation functions in support of exploration missions.

TBD-12 Closure: This IRD must be developed by Constellation Systems, in coordination with the ESMD Requirements Division. Closure of this item will be achieved no later than 90 days prior to the CEV SRR.

NSS0440H The IS^3 interface with the RPS shall comply with the requirements of the Robotic Precursor System (RPS) / In-Space Support System IRD **(TBD-89)**.

Rationale : The IS^3 will interface with the RPS to perform communication and navigation functions in support of exploration missions.

TBD-89 Closure: This IRD must be developed by Constellation Systems, in coordination with the ESMD Requirements Division. Closure of this item will be achieved no later than 90 days prior to the CEV SRR.

NSS0450G The IS^3 interface with the CDS shall comply with the requirements of the Cargo Delivery System (CDS) / In-Space Support System IRD **(TBD-90)**.

Rationale : The IS^3 will interface with the CDS to perform communication and navigation functions in support of exploration missions.

TBD-91 Closure: This IRD must be developed by Constellation Systems, in coordination with the ESMD Requirements Division. Closure of this item will be achieved no later than 90 days prior to the CEV SRR.

NSS0460C The IS^3 interface with the DSS shall comply with the requirements of the Destination Surface System (DSS) / In-Space Support System IRD **(TBD-91)**.

Rationale : The IS^3 will interface with the DSS to perform communication and navigation functions in support of exploration missions.

TBD-91 Closure: This IRD must be developed by Constellation Systems, in coordination with the ESMD Requirements Division. Closure of this item will be achieved no later than 90 days prior to the CEV SRR.

3.6 (Reserved)

3.7 Subordinate Elements (Reserved)

4 Verification (Reserved)

5 Appendices

5.1 Glossary

Abort Termination of the nominal mission that allows the crew to be returned to Earth in the portion of the space system used for nominal reentry and touchdown (see Abort to Earth, Abort to Orbit).

Abort to Earth Early mission termination, with direct return to the Earth's surface as the immediate objective.

Abort to Orbit An early mission termination that has an immediate objective of placing a crewed flight system in Earth (or destination vicinity) orbit, prior to return to the Earth's surface.

Annunciate To provide a visual, tactile or audible indication.

Ascent The function of liftoff from the Earth (or mission destination) surface, to spacecraft insertion into Earth/destination orbit.

Automated control Automatic, as opposed to human operation or control of a process, equipment or a system; or the techniques and equipment used to achieve this. Automation is the control or execution of actions with no human interaction. Automated control does not exclude the capability for manual intervention / commanding, but manual intervention / commanding is explicitly not required to accomplish the function.

Autonomous experiments Defined as a flight experiments operating independent of external commands or control (i.e. commands from mission control on Earth). Autonomous experiments can be fully automated or require some degree of manual commanding/intervention.

Autonomous operations Defined as a flight vehicle operating independent of external communication, commands or control (i.e., commands from mission control on Earth). Autonomous operations can be fully automated or require some degree of manual commanding/intervention by the onboard crew. Autonomous operations that do not require onboard crew involvement are, by definition, automated; therefore, the term "autonomous operations" used in the requirements assumes onboard crew involvement in the operations.

Berthing A method of mating two or more Exploration elements in space. During a berthing operation, the two elements are mechanically connected prior to the structural capture and final mating (i.e., one element grapples the other with a robotic arm). One element controls the trajectory and attitude of the other element for the contact and capture. Final mating is generally performed by the berthing mechanism (also see docking).

Cargo Delivery System (CDS) The CDS encompasses the capability to deliver all non-CEV flight elements needed to accomplish human exploration objectives. At such time as CDS elements dock with the CEV, they are part of a human crew occupied system, and are considered part of the CTS.

Cargo Launch Vehicle The Cargo Launch Vehicle is an element of the Cargo Delivery System. The Cargo Launch Vehicle will perform the ascent function for non-crewed elements of the CTS (EDS, LSAM), into an Earth Orbit. Since the Cargo Launch Vehicle will not carry human crew, it will not require Human-Rating.

Catastrophic Hazard A condition that may cause death or permanently disabling injury, major system or facility destruction on the ground, or major systems or vehicle destruction during the mission. (From NPR 8715.3 Safety Manual)

Consumables Resources that are consumed in the course of conducting a given mission. Includes propellant, power, habitability items (e.g., gaseous oxygen), and crew supplies.

Contingency EVA Capability An EVA capability provided to deal with critical failures or circumstances, which are not adequately protected by redundancy or other means.

Crew Exploration Vehicle (CEV) The CEV provides crew habitation and Earth reentry capability for all Exploration Spirals.

Crew Exploration Vehicle Launch Segment (CEVLS) The CEVLS consists of a Crew Exploration Vehicle (CEV), a Crew Launch Vehicle (CLV), and all the dedicated ground support infrastructure necessary to launch the CEV to Earth orbit.

Crew Launch Vehicle (CLV) The CLV is an element of the CTS. The CLV will be human-rated, and will deliver the CEV into a mission-specific Earth Ascent Target Orbit.

Crew Member Human onboard the spacecraft or space system during a mission.

Crew Survival Capabilities designed to keep the crew alive through means such as abort, escape, safe haven, emergency egress, and rescue in response to a Catastrophic Hazard.

Crew Transportation System (CTS) The CTS encompasses the flight elements needed to deliver a human crew from Earth to a mission destination, and return the crew safely to Earth. The CTS must interact with the Ground Support System (GSS) during all Spirals; current architectures require delivery of the EDS and LSAM to Earth orbit through use of the CDS.

Critical Hazard A condition that may cause a severe injury or occupational illness, loss of mission, or major property damage to facilities, systems, or flight hardware.

Day Defined as an Earth day of 24 hours.

Destination Surface System (DSS) The DSS encompasses all elements (exclusive of the surface lander that transports the crew to the destination surface) necessary to enable a long-duration human exploration mission. Examples of DSS elements include a long-duration habitation module, surface power capability, and surface transportation systems. DSS elements will be delivered to the destination surface via the CDS. It is likely that these assets will be pre-deployed in advance of the crew that will utilize them to execute a given Exploration mission.

Destination Surface to Destination Vicinity Phase Starts with the initiation of the ascent (T0) from the destination surface. Representative mission activities include: ascent, abort, and orbit insertion or libration capture. Phase ends after successful destination vicinity insertion/capture.

Destination Vicinity Operations Phase (A) Starts at the successful insertion/capture at the destination vicinity. Representative mission activities include: loiter and phasing, vehicle and system checkout, crew-cargo transfers, undocking and separation. Phase ends at the successful separation of surface lander system for descent burn.

Destination Vicinity Operations Phase (B) Starts after the successful destination orbit insertion or libration point capture, following ascent from destination surface. Representative mission activities include: phasing, vehicle-system checkout, crew-cargo transfer, undocking and separation maneuver, element disposal and/or safing. Phase ends at the completion of the Trans-Earth Injection burn.

Destination Vicinity to Earth Phase Begins with completion of Trans-Earth Injection burn and includes mid-course corrections, cruise to Earth vicinity, element separation and element disposal. Ends with arrival at Earth entry interface or insertion to Earth orbit.

Destination Vicinity to Destination Surface Phase Starts at the initiation of the descent burn from destination vicinity (destination deorbit burn or libration departure burn to destination). Representative mission activities include: descent to destination surface, descent aborts, landing, propulsion system shutdown and safing. For libration architectures, additional activities include orbit capture, phasing, and de-orbit maneuvers. Phase ends when the vehicle has completed all landing activities on the destination surface, including propulsion system shutdown and safing.

Docking A method of mating two or more Exploration elements in space. In a docking operation, the structural mechanisms are brought into contact and captured through independent control of the two vehicles' flight path and attitude. Final mating is generally accomplished by the docking mechanism (also see Berthing).

Earth Ascent Target Orbit The planned orbit, at conclusion of the ascent function.

Earth Departure Stage (EDS) EDS will be used to provide the propulsive force needed to transfer the various flight elements to destination phasing orbits (including the CEV and LSAM).

Earth-Moon Transit Transit of a spacecraft between Earth vicinity and Lunar vicinity in either direction.

Earth Orbit Operations Phase (A) Starts with completion of Earth orbit insertion. Representative activities include: phasing, rendezvous, docking and loiter. Ends with completion of a burn to leave Earth orbit (i.e., Trans-Lunar Injection burn or de-orbit burn).

Earth Orbit to Destination Vicinity Phase Starts after completion of vehicle injection burn (i.e., Trans-Lunar Injection) and includes mid-course corrections, element separation/disposal, and cruise to destination vicinity. Ends with successful insertion/capture at destination vicinity.

Earth to Orbit Phase Starts with liftoff. Representative activities include liftoff through ascent to orbit, ascent crew escape/abort and re-entry/descent during aborts, disposal of elements. Ends with insertion into a stable, 24 hour Earth orbit (i.e., at least 24-hour stability) or return to Earth (in the event of an abort).

Earth Re-entry Phase Direct re-entry returns from beyond Earth orbit begin with arrival at Earth entry interface; Earth-orbit Aerocapture return begins with completion of Earth orbit injection. In either case, phase includes descent through the atmosphere and ends with landing on the Earth's surface. This phase encompasses activities necessary to successfully execute direct-to-Earth aborts during ascent and direct entry return from beyond Earth orbit.

Earth Reference Orbit The orbit designated for assembly of Exploration System elements prior to departure for exploration destinations, defined by the following parameters: Inclination: 28.5-29.0 degrees; Launch Azimuth: 90+/- 5 degrees; Altitude: 307 km - 407 km.

Element A set of functional capabilities necessary to satisfy system-level mission objectives within a given architecture. CTS elements currently include the Crew Exploration Vehicle, Earth Departure Stage, and Lunar Surface Access Module. Elements can perform all system functions within a mission phase, or through mated operations with other exploration elements (as part of a segment).

Emergency Egress The timely and unassisted crew exit of a vehicle (i.e., in response to a Catastrophic Hazard).

Entry footprint Region on Earth’s surface defined by the boundaries of the Earth entry corridor for a given vehicle.

Equatorial Region of the Moon Defined as the area between 0-20 degrees lunar latitude (threshold), with an objective of 0-30 degrees **(TBR-7)**.

Escape Removal of crew from the failing spacecraft, due to an imminent catastrophic condition, thus placing them in a safe situation suitable for survivable return to Earth and rescue. Escape includes, but is not limited to, those capabilities that utilize a portion of the original space system for the removal (e.g., escape pods).

Exploration Spiral 1 (Crew Exploration Development and Test) Encompasses the capabilities necessary to insert humans into Earth orbit and return them safely to Earth, employing a post-Space

Shuttle flight system. The flight elements of the Exploration Spiral 1 Crew Transportation System are the Crew Exploration Vehicle and Crew Launch Vehicle. Robotic Precursor Missions that are scheduled to launch prior to the Earth orbit demonstration of the Spiral 1 CTS are considered Exploration Spiral 1 missions.

Exploration Spiral 2 (Global Lunar Access for Human Exploration) Encompasses the capabilities necessary to execute human lunar exploration anywhere on the surface of the moon. Lunar global access exploration missions will be 4-7 days in duration on the lunar surface, and do not require pre-deployed surface systems (e.g., Habitation Module or Surface Power). Robotic Precursor Missions scheduled to launch after the Spiral 1 CTS flight demonstration, and prior to the first Spiral 3 Lunar mission are considered Exploration Spiral 2 missions.

Exploration Spiral 3 (Lunar Base and Mars Testbed) Encompasses the capabilities necessary to execute a long-duration human lunar exploration campaign. This campaign requires development of extensive surface systems (e.g., habitation and surface power system). Robotic Precursor Missions that are scheduled to launch after the last Spiral 2 extended- duration lunar mission, and prior to the initial Exploration Spiral 4 mission are considered Exploration Spiral 3 missions.

Extended-Duration (Lunar Mission) Human missions to the lunar surface ranging from 4 days (96 hours) through 7 days. This capability is an objective of Exploration Spiral 2. Extended-duration lunar missions do not require pre-deployed Surface Systems (e.g., habitation modules or surface power system).

Extra-Vehicular Activity (EVA) Operations performed by crew members outside the pressurized environment of a flight vehicle or habitat (during space flight or on a destination surface).

Failure Tolerance Failure tolerance is a term used to describe minimum acceptable redundancy. It may also be used to describe similar systems, dissimilar systems, cross-strapping, or functional interrelationships that ensure minimally acceptable system performance despite failures. It is highly desirable that space flight systems performance degrades in a predictable fashion that allows sufficient time for failure detection and, when possible, system recovery even when experiencing multiple failures.

Genomics Genetic mapping and DNA sequencing of genes, with applications of the data in medicine or biology.

Geodetic Referenced to the global center of mass of any body (does not refer only to the Earth).

Ground Operations Phase Begins with the start of mission planning. Representative activities include: mission planning, training, receipt of government hardware/software, acceptance, test, checkout, repair, inspection, assembly, integration, servicing and countdown activities. Also includes ground contingency, emergency, abort and turnaround operations. Phase ends with vehicle liftoff.

Ground Support System This system provides all common ground-based capabilities on the Earth surface (e.g., mission control, launch-site processing) needed to execute Exploration missions. The GSS is not all the ground-based capabilities because some hardware is considered IS^3. Facilities and capabilities that are unique to a single Exploration System, such as the CTS, will be included as part of the system it supports.

Guidance and Control The process of directing the movements of a space vehicle, including selection of a flight path and making changes in attitude and speed.

Habitation The provision for and management of the crew environment (i.e., through the use of life support systems, thermal control, etc.) in a crewed vehicle or habitat.

In-Space Support System (IS^3) Encompass capabilities provided by space-based infrastructure elements (e.g., communications, navigation, surveillance), that are placed in orbital or lunar/planetary locations, and their corresponding ground-based operation (e.g., a ground station or antenna). These capabilities are exclusive of those provided by elements of the DSS.

Inclination The angle between the plane of an orbit and a reference plane, most frequently the equator of the central body (e.g., the Earth's equator for geocentric orbits).

Independent Technical Authority (ITA) A responsibility owned by the NASA Chief Engineer, which is then delegated through the issuance of warrants. A warrant holder is designated as compliance officer over an identified set of engineering and technical requirements or standards.

Initial Lunar Phasing Orbit Used in Spiral 2 and 3 to define the orbit from which the CEV will assume delta V responsibility for inbound rendezvous and docking with the LSAM in lunar orbit. Defined by the following parameters: Altitude: 100 km x 500 km +/**- (TBD-6)** km **(TBR-34)**; Maximum inclination error with respect to the Lunar Reference Orbit; 0.5 degrees **(TBR-28)**.

Initial Operational Capability (IOC) The capability achieved when an element, segment, or system (e.g., the CEVLS) passes its initial Flight Readiness Review in connection with a given Exploration Spiral.

Integrated Logistics Support (ILS) Is an approach that enables disciplined, unified and iterative management of support considerations into system and equipment design. ILS includes development of support requirements that are related to readiness objectives, to design, and to each other. Requirements in turn drive acquisition of required support; ILS is then employed during the operational phase.

Launch Availability The likelihood that a given launch will be achieved without a scrub once the mission timeline (first element launch for a multiple launch mission) or the launch countdown call to stations (for a mission scenario involving a single launch) has commenced. Launch availability is composed of four elements: system availability, launch probability, launch site weather constraints and abort weather constraints. Launch Availability can be expressed as: P(LA) = P(SA) x P(LP) x P(LW) x P(AW)

Where:
P(LA) = Launch Availability (overall probability of achieving a launch)
P(SA) = System Availability (probability of hardware being acceptable for launch)
P(LP) = Launch Probability (probability that the vehicle limits are not violated by upper level winds or other natural environment phenomena)
P(LW) = Launch Weather (probability that other launch site weather constraints are not violated)
P(AW) = Abort Weather (probability that abort weather constraints are not violated)

Launch Azimuth The angle formed by the projection of the flight path of the launch vehicle onto the surface of the earth's ellipsoid and the North direction, measured clockwise in degrees.

Launch Opportunity The period of time during which the relative position of the launch site and orbital plane permit a launch vehicle to perform the ascent function.

Life Support A subset of crewed vehicle (or habitat) habitation functions (i.e., a subsystem) that provides and manages breathable air, contamination control, potable water, fire detection/suppression, cabin pressure/temperature/humidity, environmental monitoring, etc.

Long-Duration (Lunar Mission) Human missions to the lunar surface that require pre-deployed Surface Systems. This capability is a requirement in Exploration Spiral 3, and encompasses surface stays from 42 days (threshold) **(TBR-3)** up to 98 days (objective) **(TBR-70)**.

Low Earth Orbit (LEO) An orbit around the Earth with a minimum orbital altitude of 170 km and is a stable orbit that will not decay rapidly because of atmospheric drag.

Lunar Architecture Focused Trade Study Ongoing engineering analysis of lunar architecture and mission design options, in support of Exploration architecture decision-making. Results of this study are captured in document ESMD-RQ-0005, "Lunar Architecture Focused Trade Study Final Results".

Lunar Ascent Orbit Used in Exploration Spirals 2 and 3 to define the orbit that the LSAM must achieve when launching from the lunar surface. Defined by the following parameters: Altitude: 100 km +/**- (TBD-8)** km; Inclination angle (wedge angle) with respect to Lunar Reference Orbit: Maximum of 10 degrees **(TBR-71)**.

Lunar Day The period of time it takes for the Moon to make one complete orbit around the Earth, due to tidal locking. It is marked from a New Moon to the next New Moon. A lunar day is officially 29 days, 12 hours, 44 minutes and 3 seconds long.

Lunar Reference Orbit Used in Exploration Spirals 2 and 3 to define the lunar orbit for rendezvous and docking of Exploration elements. Defined by the following parameters: Altitude: 100 km +/**- (TBD-8)** km; Inclination: Optimized for the mission.

Lunar Surface Access Module (LSAM) Provides crew transport to the lunar surface from the Lunar Reference Orbit and return from the surface to the Lunar Ascent Orbit; also provides limited surface habitation and EVA capabilities.

Mating The act of mechanically connecting together two major elements of a system. Mating can be performed in space, through docking or berthing, or on the ground through docking, berthing, or other interfaces.

Mission Refers to the sequence of events that must take place to accomplish prescribed scientific, technological, or engineering objective(s). Includes transportation of a flight system (robotic or human-crewed) to a destination, and operational activities at the destination (e.g., the Martian surface).

Mission Capable Refers to the status of an Exploration flight element or mated elements, which have sufficient consumables to fully execute its intended mission from its current location in space.

Mission Opportunity Refers to the Earth departure window to conduct a mission to another planetary destination such as the Moon or Mars. Typically constrained by orbital mechanics and the design of the Exploration System. If assembly of elements in Earth orbit is required, then "Mission Opportunity" refers to the departure window from Earth orbit based on the capability of the Exploration System.

Mission Phase Definitions Used as the basis for functional flow and decomposition of reference Spiral 3 human exploration mission. The Mission Phases identified were Ground Operations, Earth to Orbit, Earth Orbit Operations, Earth Orbit to Destination Vicinity, Destination Vicinity Operations (A), Destination Vicinity to Surface, Surface Operations, Destination Surface to Destination Vicinity, Destination Vicinity Operations (B), Destination Vicinity to Earth, Earth Reentry, and Recovery (see associated definitions).

Net Habitable Volume The functional pressurized volume left available to the crew after accounting for the loss of volume due to deployed equipment, stowage, trash, and any other items which decrease functional volume. The gravity environment corresponding to the habitable volume must be specified.

Objective Used in requirements language to define the desired capability above the threshold that should be evaluated for feasibility and affordability. Capabilities above the objective are not expected to be pursued or analyzed.

Payload The onboard scientific and exploration utilization (i.e. ISRU) equipment carried by a given spacecraft, generally quantified in terms of mass and volume. Also expressed as the entire mass delivered by a launch vehicle, to orbit.

Polar Regions of the Moon Defined as the area between 80-90 degrees **(TBR-74)** lunar latitude (threshold), with an objective of 70-90 degrees **(TBR-76)**.

Probabilistic Risk Assessment A comprehensive, structured, and logical analysis methodology employed to identify and assess risks in technologically complex systems. Probabilistic Risk Assessment results can be used to develop or validate Fault Trees and Failure Modes analysis. They also can be used as a tool for making design and logistics decisions.

Proteomics Analyzing structure, function, and interactions of the proteins produced by the genes of a particular cell, tissue or organism, with applications of the data to medicine or biology.

Proximity Operations Phase of flight operations (near the end of rendezvous and prior to docking; or after undocking) during which two space vehicles are at close ranges (< 1 km) and low relative velocity.

Recovery Phase Begins with completion of Earth surface landing and includes recovery forces operations, vehicle safing, vehicle configuration for recovery, crew egress, crew return to post-mission facilities. Ends with vehicle recovery to post-mission facilities for refurbishment or disposal.

Regolith Fine-grained powdery layer on the lunar surface above the bedrock.

Remotely Commanded Operations The capability to operate a vehicle, system, or subsystem from an external location (e.g., mission control). Remotely commanded operations do not require the presence of an onboard crew.

Rescue The process of locating the crew, proceeding to their position, and transporting them to an appropriate location.

Robotic Precursor Mission A robotic spacecraft mission that supports The Vision by achieving scientific objectives and/or through preparing for future human exploration activities.

Robotic Precursor Phase Exploration missions accomplished by robotic systems, to prepare for and support future human exploration missions.

Robotic Precursor System Robotic spacecraft that are developed to execute missions that prepare for and support future human exploration, and to accomplish science objectives.

Safety-Critical Software Software is safety-critical if it meets at least one of the following criteria:
1. Resides in a safety-critical system (as determined by a hazard analysis AND at least one of the following:
   a. Causes or contributes to a hazard.
   b. Provides control or mitigation for hazards.
   c. Controls safety-critical functions.
   d. Processes safety-critical commands or data.
   e. Detects and reports, or takes corrective action, if system reaches hazardous state.
   f. Mitigates damage if a hazard occurs.
   g. Resides on the same system (processor) as safety-critical software.
2. Processes data or analyzes trends that lead directly to safety decisions (e.g., determining when to turn power off to a wind tunnel to prevent system destruction.)
3. Provides full or partial verification or validation of safety-critical systems, including hardware or software subsystems.

Segment Used in the CTS requirements development process to express the identity of two or more elements mated together and operating jointly in a given set of mission phases. Segments defined this way facilitate functional decomposition of capabilities throughout the reference Exploration Spiral 3 mission. For example, the In-Space Transportation Segment is comprised of the CEV and an Earth Departure Stage, and comprises the CTS from the Earth Orbit Operations Mission Phase until CEV-EDS separation during the Destination Vicinity Operations Mission Phase. Other segments were defined as the CEV Launch Segment (CEV and CLV operating through separation in Earth orbit), the Destination Transportation Segment (CEV and LSAM operating in the lunar vicinity), and the Earth Return Segment (CEV only, upon separation from LSAM Ascent Stage).

Spiral Development Process A phased system of systems development process that allows increasing capabilities to be achieved in support of long range objectives. While work can be accomplished concurrently against the objectives associated with multiple spirals, the completion of all objectives for a given spiral is considered necessary to enable achievement of the succeeding spiral. See associated definitions for Exploration Spirals.

Strategy to Task to Technology Process (STTP) Use of engineering analysis to validate architectural and mission design approaches, and identify technology investment needs.

Surface Operations Phase Starts at the completion of landing on the destination surface, including propulsion system shutdown and safing. Representative mission activities include: science operations, system and operational testing, surface EVA, assembly and maintenance, vehicle checkout, and preparation for ascent. Phase ends at initiation of ascent from the destination surface (i.e., T0).

System A set or arrangement of interdependent elements/segments that are used to accomplish mission objective(s). Exploration systems are Crew Transportation, Cargo Delivery, In-Space Support, Destination Surface, Robotic Precursor, and Ground Support. These systems comprise the Exploration System of Systems.

System of Systems A set or arrangement of interdependent systems that are related or connected to provide a given capability. The loss of any portion of the System of Systems will degrade the performance or capabilities of the whole. The systems contained in the Exploration System of Systems (ESS) are: the Crew Transportation System, Cargo Delivery System, In-Space Support System, Destination Surface System, Robotic Precursor System, and Ground Support System. Requirements, constraints, and guidelines that apply to all human and robotic exploration systems are levied against the Exploration System of Systems, and may apply against any or all Exploration Spirals, as specified. The term “System of Systems” is sometimes expressed synonymously as “Super-system”.

Threshold Used in requirements language to define the minimum capability necessary to satisfy the requirement.

Transfer Volume The passageway between two connected element that can contain crew.

Wedge Angle The angle existing between two orbital planes. A plane change maneuver must be accomplished (i.e., through the use of delta-V capability) to negotiate the wedge angle between a given initial orbit plane (e.g., the Earth Reference Orbit) and a desired target orbital plane (e.g., the Lunar Reference Orbit).

5.2 Acronyms

AA	Associate Administrators
AFS	Air Force Station
AIM	Advanced Integrated Matrix
AO	Announcement of Opportunity
CDS	Cargo Delivery System
CE&R	Concept Exploration and Refinement
CEV	Crew Exploration Vehicle
CEVLS	Crew Exploration Vehicle Launch Segment
CLV	Crew Launch Vehicle
CG	Center of Gravity
CRaTER	Cosmic Ray Telescope for the Effects of Radiation
CTS	Crew Transportation System
DI	Digital Model
DSN	Deep Space Network
DSS	Destination Surface System
EDR	Experimental Data Record
EDS	Earth Departure Stage
EI	Entry Interface
EIR	Enterprise Independent Review

ECLSS	Environmental Control/Life Support System
EPO	Education and Public Outreach
ESMD	Exploration Systems Mission Directorate
ESS	Exploration System of Systems
EVA	Extra-Vehicular Activity
FOM	Figures-of-Merit
FOV	Field of View
GCR	Galactic Cosmic Ray
GSFC	Goddard Space Flight Center
GN&C	Guidance, Navigation, and Control
GSS	Ground Support System
HR&T	Human & Robotic Technology
HWHM	Half width and Have Maximum (of the instrument field of view)
IA	Independent Assessment
IA	International Agreement
IIR	Independent Implementation Review
INSTEP	In-Space Technology Experiments Program
IOC	Initial Operational Capability
IPAO	Independent Projects Assessment Office
IRD	Interface Requirements Document
ILS	Integrated Logistics Support
IRT	Independent Review Team
IS^3	In-Space Support System
ISRU	In-Situ Resource Utilization
ITA	Independent Technical Authority
JIMO	Jupiter Icy Moon Orbiter
K	Kelvin
km	Kilometers
KPP	Key Performance Parameters
KSC	Kennedy Space Center
LAMP	Lyman-Alpha Mapping Project
LAWG	Lunar Architecture Working Group
LEND	Lunar Exploration Neutron Detector
LEO	Low Earth Orbit
LET	Linear Energy Transfer
LExSWG	Lunar Exploration Science Working Group
LOA	Letter of Agreement
LOLA	Lunar Orbiter Laser Altimeter
LRO	Lunar Reconnaissance Orbiter
LROC	Lunar Reconnaissance Orbiter Camera
LRL	Lunar Robotic Lander
LRO	Lunar Robotic Orbiter
LROC	Lunar Robotic Orbiter Camera
LSAM	Lunar Surface Access Module
LSI	Landed Surface Interrogator
m	Meters
M	Meters
MEPAG	Mars Exploration Program Analysis Group

MeV	Mega-electron Volts
mm	Millimeters
MOU	Memorandum of Understanding
NAC	Narrow Angle Camera
NAR	Non-Advocate Review
NEDD	Natural Environments Definition for Design
NODIS	NASA Online Directives Information System
NP	NASA Publication
NPD	NASA Policy Documents
NPR	NASA Procedural Requirement (Document)
NPSD	National Security Presidential Directive
NRA	NASA Research Announcements
OAG	Operations Advisory Group
ORDT	Objectives and Requirements Definition Team
OSMA	Office of Safety and Mission Assurance
OSP	Orbital Space Plane
PDR	Preliminary Design Review
PDS	Planetary Data System
PI	Principal Investigator
PIP	Proposal Information Package
PMC	Program Management Council
ppm	Parts Per Million
PRA	Probabilistic Risk Assessment
PSR	Permanently Shadowed Regions
RFP	Request for Proposals
RLEP	Robotic Lunar Exploration Program
RPS	Robotic Precursor System
SMD	Science Mission Directorate
SNR	Signal-to-Noise Ratio
SPE	Solar Particle Event
SRR	System Requirements Review
STD	Standard (Document)
STTP	Strategy to Task to Technology Process (or Panel)
TBD	To Be Determined
TBR	To Be Resolved
TPS	Thermal Protection System
TRL	Technology Readiness Level
TTA	Technical Assistance Agreements
WAC	Wide Angle Camera
UV	Ultraviolet

5.3 Requirements Taxonomy

The following table is provided as a key to understanding the taxonomy used for requirement Unique ID numbers (i.e., the Unique ID number is shown at the beginning of each requirement statement).

System/Segment/Element	Req. Number	Spiral
ESS (Exploration System of Systems Technical)	**0001 - 9999**	**A = Spiral 1**
EPR (Exploration Programmatic Requirements)		**B = Spiral 2**
EPG (Exploration Programmatic Guidelines)		**C = Spiral 3**
GSS (Ground Support System)		**D = Spiral 4**
NSS (In-Space Support System)		**E = Spiral 5**
CTS (Crew Transportation System)		**F = Spirals 1&2**
CVS (CEV Launch Segment)		**G = Spirals 2&3**
CEV (Crew Exploration Vehicle)		**H = Spirals 1,2,3**
CLV (CLV Launch Vehicle)		

5.4 Requirements Traceability Tables

The following traceability table provides a summary of parent-child traceability from ESS Technical Requirements (ESMD-RQ-0010) to the appropriate IS^3 Requirements Document.

ESS Parent	IS^3 Child
ESS0680	NSS0120H
ESS0680	NSS0180H
ESS0680	NSS0190H
ESS0680	NSS0200H
ESS0680	NSS0220H
ESS0570	NSS0250H
ESS0680	NSS0280H
ESS0360	NSS0320H
ESS0570	NSS0330H
ESS0350	NSS0340H
ESS0570	NSS0350H
ESS0370	NSS0370H
ESS0120	NSS0400H
ESS0090	NSS0400H
ESS0650	NSS0410H
ESS0120	NSS0420H
ESS0100	NSS0420H
ESS0570	NSS0430H
ESS0680	NSS0430H
ESS0570	NSS0440H
ESS0680	NSS0450G
ESS0680	NSS0460C